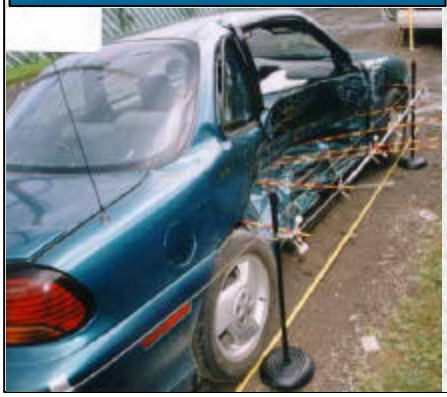
CIREN

Children's National Medical Center
Washington, DC



Predictors of Serious Childhood Injury in Side Impact Motor Vehicle Crashes

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I would like to talk to you about some of the patterns of injury and restraint misuse we have seen as part of our investigation into the Biomechanics of injuries to restrained children in motor vehicle collisions.

The effectiveness of safety restraints in protecting children from motor vehicle injuries has been well documented, prompting all states to require that child passengers ride in appropriate restraints. Although the prevalence of child restraint device use has increased following the passage of child restraint device laws, many drivers use restraints incorrectly on their child passengers.

Methods

- Analyze MVC's involving injured children < 16 yrs old for the independent predictors of sustaining a serious injury based on demographic, vehicular, and behavioral factors
- Dataset limited to:
  - Frontal and Lateral impacts

The purpose of this study was to analyze the CNMC CIREN motor vehicle crash data that involved injured children <16 yrs old to identify the descriptive characteristics of lateral vs frontal impact crashes.

Secondarily, we sought to identify what demographic, vehicular, and behavioral factors could independently predict sustaining a serious injury in this population.

The dataset was limited to frontal and lateral impacts only.

Methods

Variables Examined

- **Crash type**
  - Lateral vs Frontal
- **Injury Severity**
  - AIS 3+, AIS 4+
- **Child Characteristics**
  - age group, sex, BMI, ICU admits, hospital LOS, body region injured, restraint use and misuse
- **Driver Characteristics**
  - driver age, was driver restrained, # people in car
- **Vehicle Characteristics**
  - delta V, any intrusion, age of car, child seating position, injury contact points

The variables we examined included:

- **Crash type**

  Lateral vs Frontal Crashes

- **Injury Severity**

  Dichotomized in any AIS 3+ and any AIS 4+ injury

- **Child Characteristics**

  Age group, sex, body mass index, ICU admission, hospital length of stay, body region injured, restraint appropriateness and misuse

- **Driver Characteristics**

  Driver age, driver restraint status, # people in car

- **Vehicle Characteristics**

  Delta V, any vehicular intrusion, age of car, child seating position, injury contact points

Methods

CNMC Inclusion Criteria

- Children < 16 Years Old
- Admitted to Trauma Service
- Restrained MVC Passengers

At the Children's Hospital CIREN center, the population we are recruiting consists of children who are:

1. Children < 16 Years Old
2. Admitted to Trauma Service
3. Restrained MVC Passengers

Methods

CNMC Exclusion Criteria

- Unrestrained Passenger
- ED Treated & Released
- Vehicle > 6 Years Old
- Unable to Locate Vehicle

Cases are excluded if the patient is:

1. Unrestrained
2. Treated in the ED & released
3. The vehicle is > 6 years old
4. The vehicle could not be located for investigation

The focus on our investigation is on the recent model year vehicles so that the crashworthiness of the vehicles is relatively consistent across all CIREN centers.

CNMC Population

1991-2000

- 196 Cases
  - 54% Female
- Mean age = 6 Years
  - 39% < 5 Years Old
- Median ISS = 6
- Hospital LOS = 2 days

We have complete data on 196 cases that date back to 1991.

- The population has slightly more females than males.
- The mean age = 6;
- 1/3 of the population is < 5 yrs of age
- The median injury severity score = 6 and
- The median hospital length of stay = 2 days

Child Restraint Systems

- RF Safety Seats for Infants
- FF Child Safety Seats
- Convertible Seats
- Booster Seats
- Lap/Shoulder Safety Belts

One of the aims of our research is to learn more about the injury patterns that result from different types of restraint misuse, thereby channeling resources towards preventing the types of misuse more likely to result in injury to the child.

Despite an enormous effort by child safety advocates such as SafeKids, misuse of child restraint systems continues to be unacceptably high in the United States with misuse rates reported as high as 85%.

Child Restraint Issues

- Variety of Restraint Devices
- Appropriate for Child Size and Weight
- Correctly Installed in Vehicle
- Various Seat/Seatbelt Configurations
- Details of Restraint Usage at Scene Occasionally Unknown

Some of the issues that we need to assess when evaluating effective child restraint use include:

1. There are a variety of child restraint devices from which to choose
2. The restraint needs to be appropriate for the child's size and weight
3. Is the restraint correctly installed in the vehicle
4. There are various seat and seatbelt configurations to consider
5. The details of how the child was restrained at the scene may occasionally remain unknown even after investigation

Evaluating Restraint Use

- **Appropriate**:
  - Was this the Appropriate Type of Restraint for Child in Relation to Age and Weight
- **Misuse**:
  - How the Restraint Was Used. Categorized as:
    - no misuse
    - any CSS misuse
    - any Belt misuse

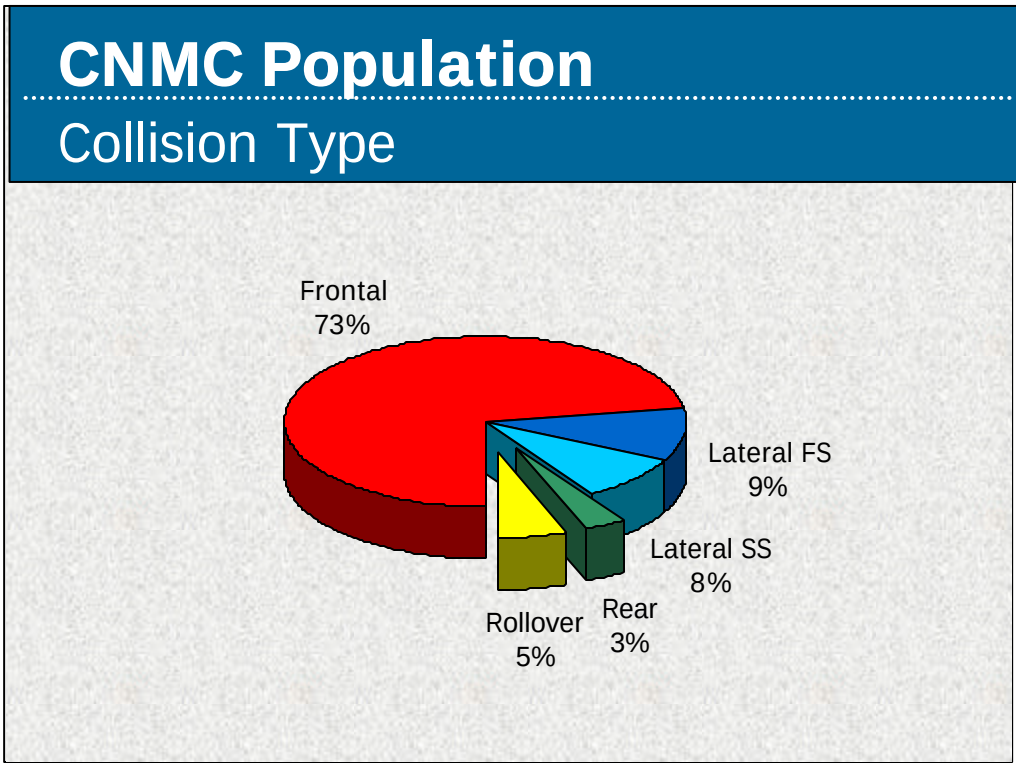
Two factors we assess when evaluating child restraint usage:

1. Was the child restraint that was used appropriate for that child's age, height, and weight; and

2. Was the restraint used properly with respect to how it secured the child independent of whether it was appropriate

CNMC Population

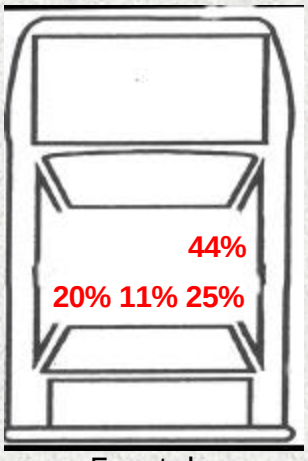
Collision Type



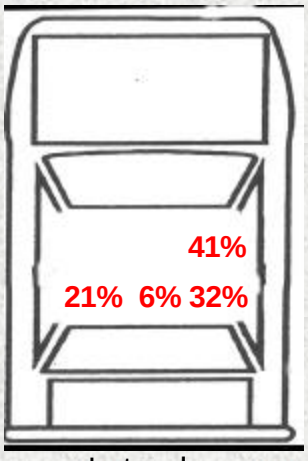
Almost 3/4 of the CNMC cases involved a frontal crash while another 17% involved lateral impact crashes.

Eight percent of the cases were lateral impacts on the same side of the vehicle where the child was sitting while another 9% were on the far side of the vehicle.

Seating Position by Crash Type



Frontals
(n=145)



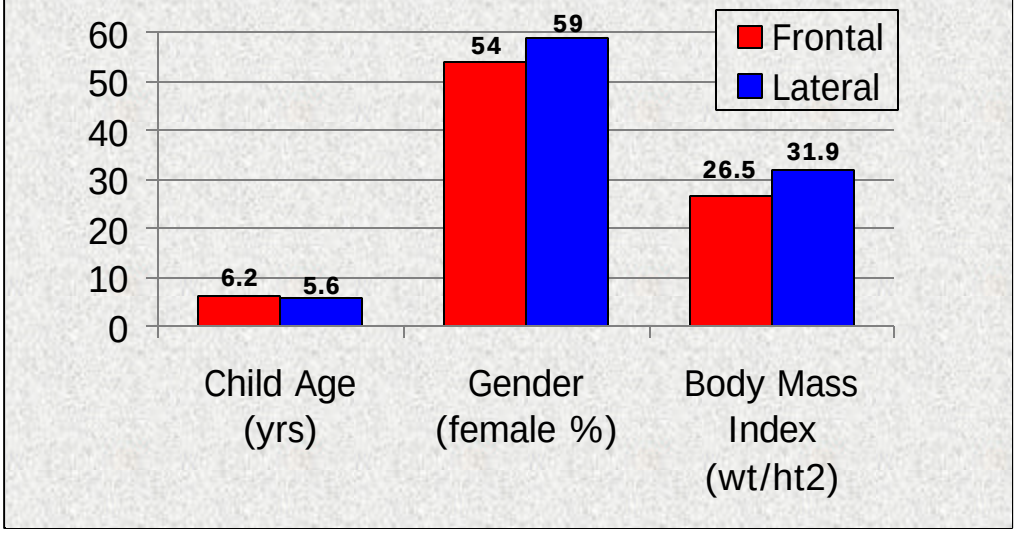
Laterals
(n=34)

More than 40% of the children were sitting in the right front seating position, placing them at increased risk for injury.

Almost one-half of the lateral impact cases were sitting on the same side of the crash: 11 in front and 5 in the rear

Frontal vs Lateral Crashes

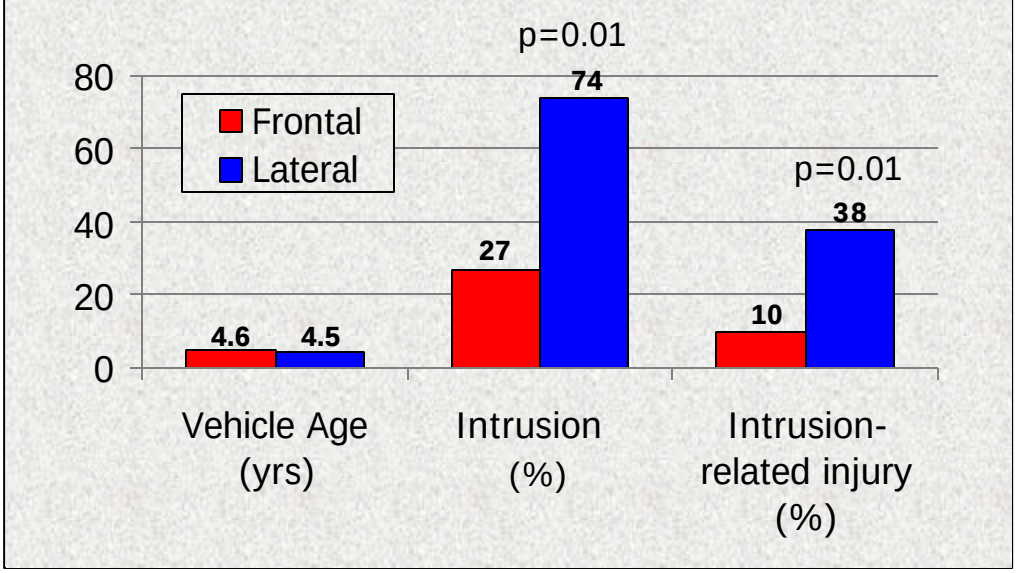
Child characteristics



There were no differences between lateral impact and frontal impact cases with respect to the age, sex or body mass index of the injured children

Frontal vs Lateral Crashes

Vehicle characteristics

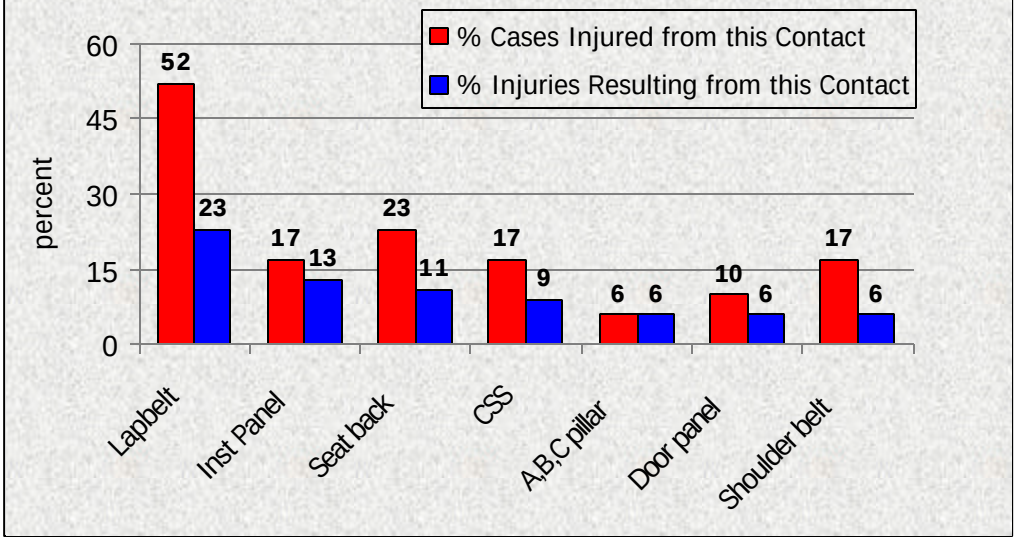


There was an expected significant difference in intrusion between lateral impact and frontal impact cases.

Three of four lateral impact cases incurred some degree of intrusion and 38% of the victims in lateral impacts suffered at least 1 intrusion-related injury compared to an intrusion rate of 27% and an intrusion-related injury of 10% for frontal impacts.

Frontal Crashes

Injury Contact Points

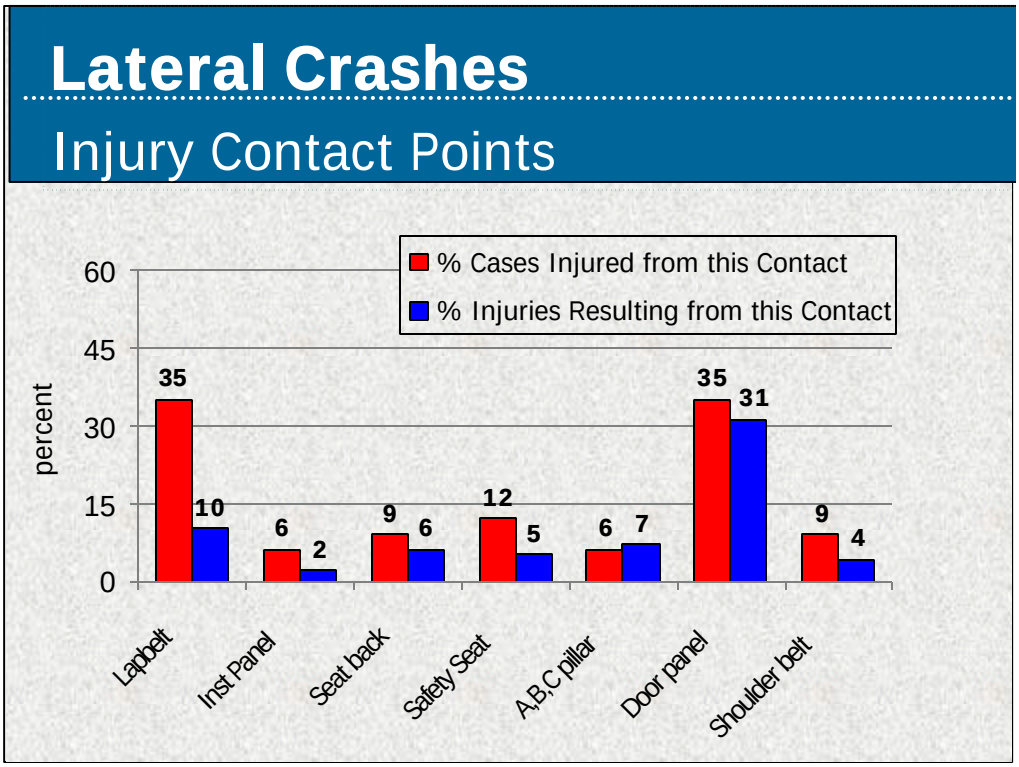


Lapbelts were the primary source of contact for injuries that occurred in frontal crashes, accounting for at least 1 injury in more than 1/2 of the cases. Lapbelts were also responsible for 23% of all the injuries documented in this population.

The next most common source of injury in frontal crashes was the the seat back (23% of population injured), followed by the instrument panel (17% of population injured) , child safety seat (17% of population injured) and shoulder belt (17% of population injured).

Lateral Crashes

Injury Contact Points

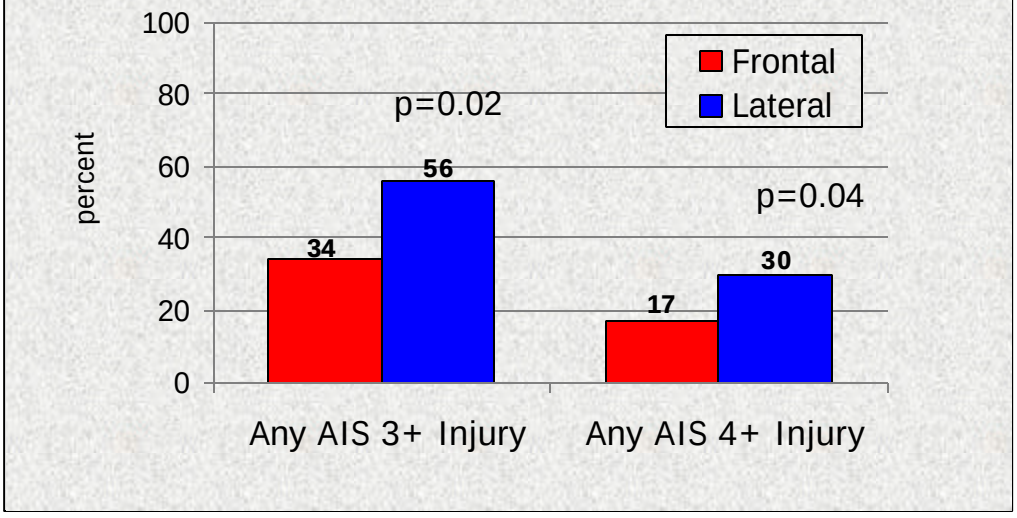


The side door panel was the primary source of contact for injuries sustained in lateral crashes, accounting for at least one injury in more than 1/3 of the cases. The door panel was responsible for 31% of all the injuries documented in lateral impacts.

The next most common sources of injury in lateral crashes were lapbelts (35% of population injured) and child safety seats (12% of population injured)

Frontal vs Lateral Crashes

AIS Scores



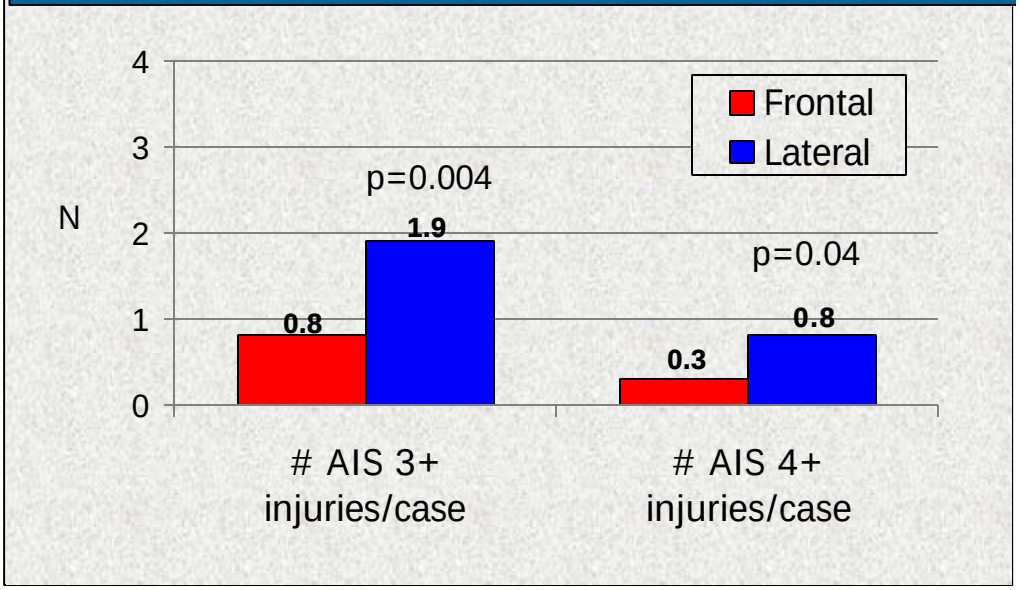
Lateral impact crashes resulted in significantly more children being injured severely than frontal crashes.

More than 1/2 of the children injured in lateral impacts suffered at least 1 injury with an injury severity score of AIS 3 or greater compared to 34% of frontal crashes.

30% of the children injured in lateral impacts suffered at least 1 injury with an injury severity score of AIS 4 or greater compared to 17% of frontal crashes.

Frontal vs Lateral Crashes

AIS Scores



Lateral impact crashes also resulted in significantly greater number of severe injuries per child than frontal crashes.

Children injured in lateral impacts suffered nearly 2 injuries per case with an injury severity score of AIS 3 or greater compared to 0.8 per case for frontal crashes.

Lateral impacts also resulted in significantly more AIS 4 or greater injuries per case compared to frontal crashes (0.8/case vs 0.3/case).

Frontal vs Lateral Crashes

AIS 4+ Leading Injury Diagnoses

AIS 4+ Diagnoses	Frontal (%, rank)	Lateral (%, rank)
• Intracranial Injury	71, 1	90, 1
• Internal Abdomen,Pelvis	58, 2	70, 3
• Lower Extremity Injury	42, 3	70, 3
• Internal Chest Injury	29, 4	80*, 2

* $p < .01$

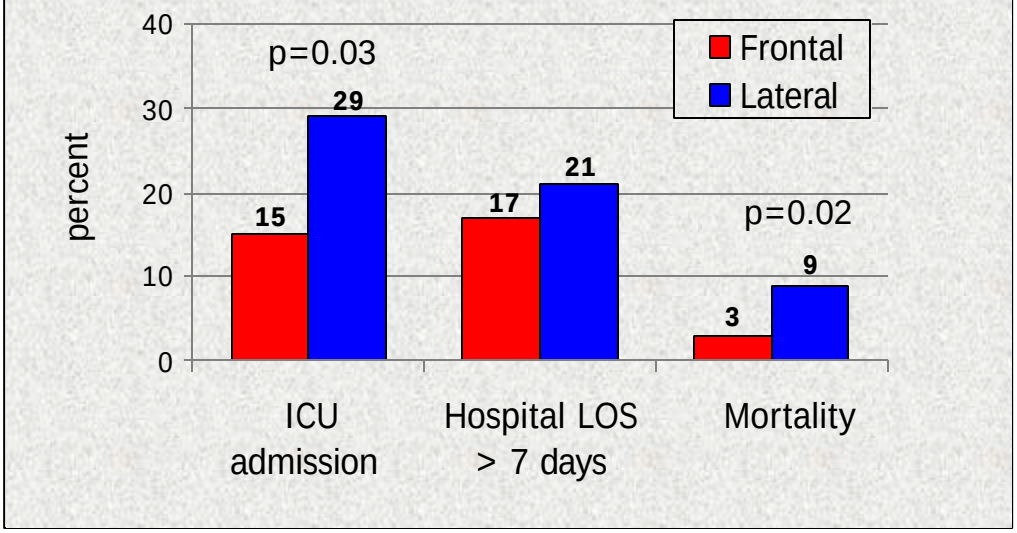
Internal injury to the head was the most frequent injury diagnosis for both frontal and lateral impact crashes accounting for injury in 71% and 90% of the cases respectively.

The second most common injury diagnosis in frontal impacts was internal abdomen or pelvic injury (58% of cases injured), followed by lower extremity injury (42% of cases injured), and internal chest injury (29% of cases injured)

Lateral impacts had a slightly different injury pattern with a significantly greater percentage of internal chest injuries than frontal impacts (80% vs. 29% of cases injured), followed by internal abdomen or pelvic injury and lower extremity injury (70% of cases injured each)

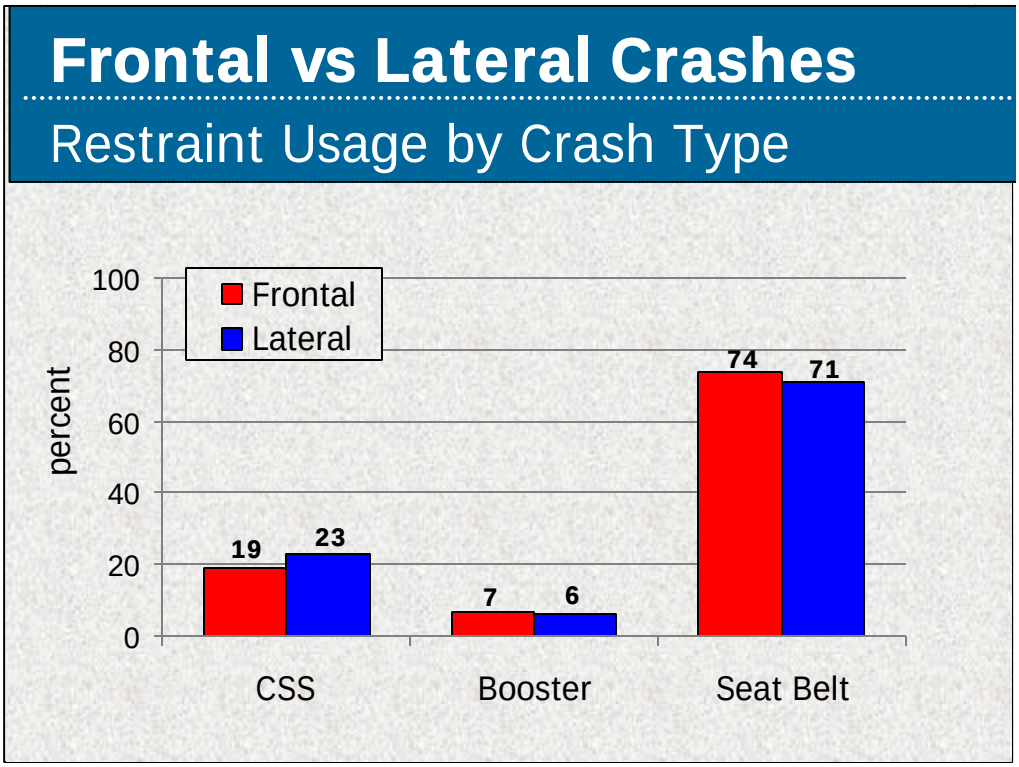
Frontal vs Lateral Crashes

Other Injury Severity Indices



Because of the significantly greater number of severe injuries seen in lateral impacts vs frontal impacts, lateral impacts demonstrated some expected differences in morbidity patterns

Although there was no difference between the 2 groups in hospital length of stay > 7 days, twice as many lateral impact cases were admitted to the ICU (29% vs 15%) and there was a significantly greater mortality rate among lateral impacts, although the total number of fatal cases overall was small (9 cases).



There were also no differences between the two crash types regarding how the injured child was restrained.

Approximately 3/4 of the population was restrained with some type of belt restraint and the remaining 25% of children were restrained in a child safety seat. Only 7% of the population used a booster seat.

Frontal vs Lateral Crashes

Restraint Misuse by Crash Type

Belted Passengers	Frontal (%)	Lateral (%)
• Shoulder belt not worn, behind back, under arm	21	12
• Lap belt not worn	4	6
CSS Passengers		
• Seat Direction	10	9
• Vehicle Safety Belt Use	8	3
• More than 1 CSS misuse	15	0

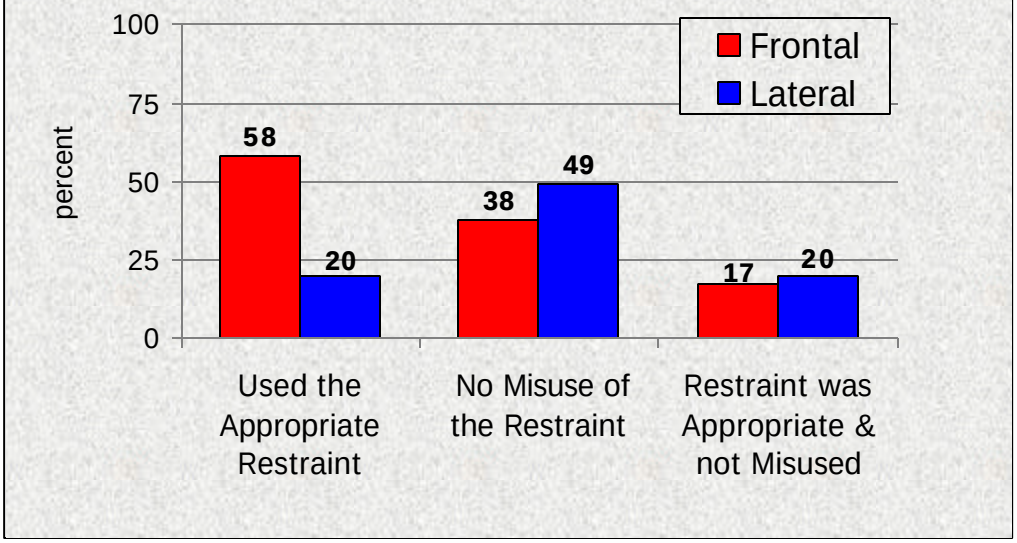
The most common misuse of a restraint system was placing the shoulder harness of a lap/shoulder belt complex behind the child's back or under the arm (21% of frontal injured children, 12% of lateral cases)

The most common misuse of a child safety seat involved having a rear-facing infant safety seat in the forward-facing position before the child was 1 year of age or weighed 20 lbs.

Fifteen percent of the drivers involved in frontal impact crashes committed more than one misuse while restraining their child in a child safety seat.

Frontal vs Lateral Crashes

Restraint Misuse by Crash Type



This slide displays the percent of the population that restrained their child appropriately and without misuse.

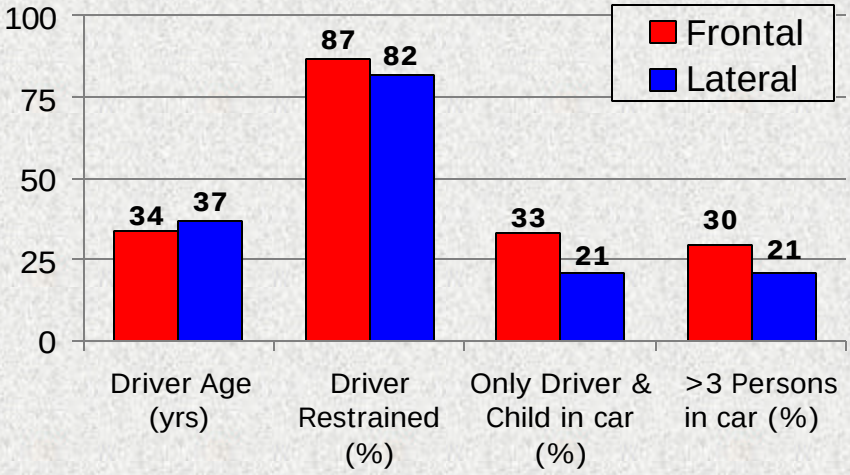
Children in lateral impacts were less likely to have been in the appropriate restraint for their age and weight than frontal impacts (20% vs 58%).

Less than 1/2 of both lateral and frontal impact cases used the restraint system properly with respect to how it secured their child in the vehicle.

In combination, only 17% of children in frontal impacts and20% of those in lateral impacts were restrained with both the appropriate restraint for that child's age and weight and did not misuse the restraint in any manner.

Frontal vs Lateral Crashes

Driver/occupant characteristics



More than 80% of all the drivers were reported to be wearing their seatbelts at the time of the crash.

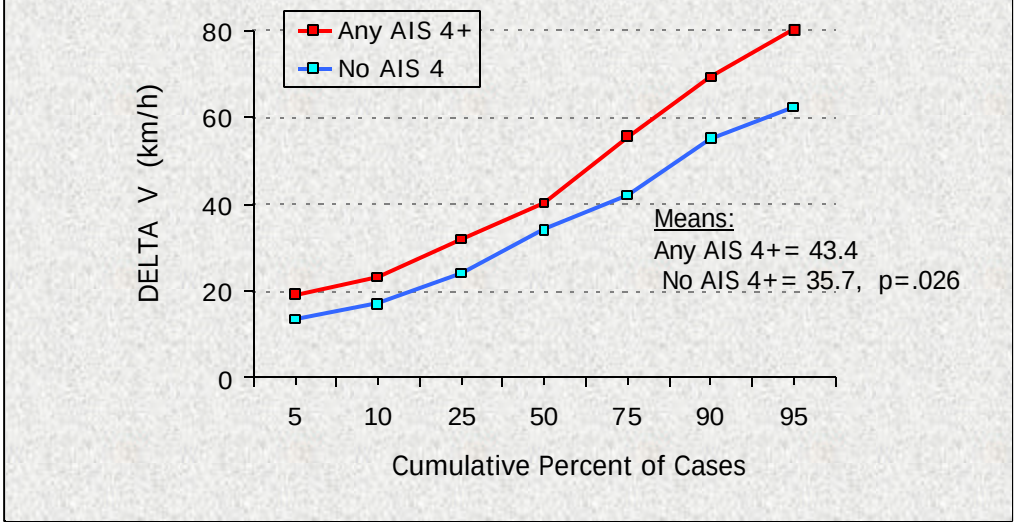
We examined whether the age of the driver or the number of persons in the car at the time of the crash could be markers of potential distraction for the driver and for improperly restraining their child. Two dichotomous variables were created:

- crashes with only the driver and the child in the car (least likely to be distracted) and
- those with 4 or more persons in the car (more likely to be distracted).

Neither the age of the driver or the number of persons in the car differed among the 2 crash types.

AIS 4+ Crashes

Delta V



The cumulative frequency of Delta V was examined contrasting children that sustained any AIS 4+ injury with those that did not. Only frontal crashes were examined because of the lack of comparability of Delta V between lateral vs frontal impacts.

It was expected that AIS 4+ injured children would be involved in more severe crashes than children with no AIS 4+ injuries.
As expected, Delta V was significantly greater for cases that sustained any AIS 4+ injury at every cumulative frequency cutpoint shown on the graph above.

Predictors of Serious Injury

Logistic Regression

- Taking many categorical or continuous IV to predict a dichotomous outcome (y,n)
- Permits adjustment of odds ratio for potential confounders
- Only relevant predictors included in model:
  - significant bivariates
  - other plausible variables
  - no 2 IV are highly correllated
- Rule of thumb: ~25-30 cases/variable

Logistic regression was used identify potential predictors of sustaining an AIS 4+ injury. Logistic regression takes many categorical or continuous independent variables to predict a dichotomous outcome (any AIS 4+ injury vs. no AIS 4+ injury). It permits the adjustment of crude odds ratios for potential confounders and interactions

Only relevant predictors are to be included in model:

- Significant bivariates
- Other biologically or biomechanically plausible variables
- No 2 IV should be highly correllated to each other
- Rule of thumb: use approximately 25-30 cases/variable

Predictors of AIS4+ Injury

Variables entered: Hierarchical LR model

Demographic

- Sex
  male, female
- Age
- Body Mass Index

Behavioral

- Used Appropriate Restraint
  yes, no
- Restraint Misuse
  no misuse
  CSS or belt misuse

Crash

- Crash Type
  frontal, lateral
- Vehicle Intrusion
  yes, no
- Delta V

Based on descriptive analyses, the following variables were entered into a forward stepwise model where the computer chooses the best model: Sex (male, female); Age, Body mass index, Restraint misuse (no misuse, any belt or safety seat misuse), Used the appropriate restraint (yes, no), Crash type (frontal, lateral) Vehicle Intrusion (yes, no), and Delta V

The same variables were then entered in a hierarchical model where the variables were forced in the following order:

Step 1: Demographic variables

Step 2: Behavioral variables

Step 3: Crash variables

Both models were significant, fit the model well, and produced similar results. Linear regression revealed no interactions to be present in the final model.

Adjusted Odds Ratios

Predictors of AIS 4+ Injury

Variable	*Adjusted OR (95% CI)*	*p*
Gender		
Female	2.8 (1.1, 7.7)	p=.04
Male	1.0	
Crash Type		
Lateral	3.6 (1.1, 11.5)	p=.03
Frontal	1.0	
Delta V	1.1 (1.01, 1.1)	p=.01
Restraint Misuse		
Any misuse	3.7 (1.4, 10.0)	p=.008
No misuse	1.0	

There were 4 factors independently associated with the risk for sustaining an AIS 4+ injury:

- Females were 2.8 times more likely to be injured than males after controlling for demographics, restraint use and vehicular factors.
- Lateral impacts were 3.6 times more likely to result in a child sustaining an AIS 4+ injury
- Any misuse of the restraint system resulted in a 3.7 greater risk for an AIS 4+ injury.
- Delta V resulted in a 10% greater risk for AIS 4+ injury.

Adjusted Odds Ratios

Predictors of AIS 4+ Head Injury

Variable	*Adjusted OR (95% CI)*	*p*
Gender		
Female	4.3 (1.3, 14.4)	p=.02
Male	1.0	
Vehicle intrusion		
Yes	3.2 (1.1, 10.2)	p=.047
No	1.0	

Because head injuries were so prevalent in our population (81% of all cases sustained some type of head injury), a second regression model was run to look at predictors of only AIS 4+ head injuries.

There were 2 factors independently associated with the risk for sustaining an AIS 4+ head injury:

- Female head injury risk was more than 4 times that of males after controlling for demographics, restraint use and vehicular factors.
- Vehicle intrusion predicted a 3.2 greater risk for sustaining an AIS 4+ head injury,

Conclusions

- Lateral impacts were 3.6 times more likely to result in a child sustaining an AIS 4+ injury
- Females demonstrated significant increased risk for sustaining serious injury:
  - 3-fold increase for any AIS 4+ injury
  - 4-fold increase for AIS 4+ head injury

Conclusions

- Child restraint misuse was independently associated with a nearly 4-fold increased risk for sustaining an AIS 4+ injury
- Vehicular intrusion was associated with a 3-fold increase risk for an AIS 4+ head injury
- Delta V was associated with a 10% increased risk for sustaining an AIS 4+ injury

Conclusions

- No associations were seen between AIS 4+ injuries and
  - age
  - appropriate restraint usage

Other Applications of Logistic Regression in MCV Research

JAMA June 7, 2000 - vol 283 (21)

Rivera FP, Koepsel TD, Grossman DC, Mock C

Effectiveness of Automatic Shoulder Belt Systems in Motor Vehicle Crashes

The following reference is recommended as an example of the application of multivariate logistic regression to motor vehicle crash data using the NASS data system.